PRELIMINARY FIELD EVALUATION OF MERCURY CONTROL USING COMBUSTION MODIFICATIONS

Quarterly Report

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Abstract

In this project General Electric Energy and Environmental Research Corporation conducts a preliminary field evaluation of a novel technology, referred to as Hg/NO_x, that can reduce emissions of both mercury (Hg) and oxides of nitrogen (NO_x) from coal-fired power plants. The evaluation takes place at Green Station operated by Western Kentucky Energy. Reduction of Hg and NO_x emissions in Units 1 and 2 is achieved using coal reburning. Units 1 and 2 are sister units with similar boiler parameters and unit's configurations. Activities during the current reporting period (April 23 – July 22, 2004) included measurements of Hg emissions in Unit 1. Goal of testing was to characterize Hg emissions while tuning the reburn/overfire air systems for maximum NO_x control performance while maintaining acceptable boiler thermal performance. Testing demonstrated that Hg emissions at ESP outlet varied from 6 to 10 $\mu g/m^3$. Measurements also demonstrated that most Hg in flue gas was present in the oxidized form. Testing showed that efficiency of Hg removal at ESP outlet varied from 6% to 36%.

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Executive Summary

In this project General Electric Energy and Environmental Research Corporation conducts a preliminary field evaluation of a novel technology, referred to as Hg/NO_x, that can reduce emissions of both mercury (Hg) and oxides of nitrogen (NO_x) from coal-fired power plants. The evaluation takes place in Green Station Units 1 and 2 located near Henderson, Kentucky and operated by Western Kentucky Energy. Units 1 and 2 are sister units with similar boiler parameters and unit's configurations. Reduction of Hg and NO_x emissions in Units 1 and 2 is achieved using coal reburning. The program comprises field and pilot-scale tests, engineering studies and consists of five tasks. Activities during previous reporting period (January 23 – April 22, 2004) included measurements of Hg emissions in Unit 2 while optimizing reburning system to minimize NO_x emissions and LOI. Activities during the current reporting period (April 23 – July 22, 2004) included measurements of Hg emissions in Unit 1. Goal of testing was to characterize Hg emissions while tuning the reburn/overfire air systems for maximum NO_x control performance while maintaining acceptable boiler thermal performance. Data obtained in Unit 1 will be later used to optimize Unit 2 reburn system for Hg control. Testing demonstrated that Hg emissions at ESP outlet varied from 6 to 10 $\mu g/m^3$. Measurements also demonstrated that most Hg in flue gas was present in the oxidized form. Testing showed that efficiency of Hg removal at ESP outlet varied from 6% to 36%.

1.0 Introduction

In this project General Electric Energy and Environmental Research Corporation (EER) conducts a preliminary field evaluation of a novel technology, referred to as Hg/NO_x, that can reduce emissions of both mercury (Hg) and oxides of nitrogen (NO_x) from coal-fired power plants. The evaluation takes place in Green Station Units 1 and 2 located near Henderson, Kentucky. Green Station is owned and operated by Western Kentucky Energy (WKE). Units 1 and 2 fire blend of bituminous coals and are equipped with cold-side ESPs and wet scrubbers. Reduction of Hg and NO_x emissions in Units 1 and 2 is achieved using coal reburning.

The program comprises field and pilot-scale tests, engineering studies and consists of five tasks. Activities during previous reporting period (January 23 – April 22, 2004) included measurements of Hg emissions in Unit 2 while optimizing reburning system to minimize NO_x emissions and LOI. Testing showed that as a result of combustion optimization NO_x under reburning conditions decreased from 0.22 lb/MBtu to 0.13 lb/MBtu. Mercury removal efficiencies at ESP outlet were in the range of 30-40%. Testing showed that the efficiency of Hg removal increased as ESP temperature decreased.

Activities during the current reporting period (April 23 – July 22, 2004) included measurements of Hg emissions in Unit 1. Units 1 and 2 are sister units with similar boiler parameters and unit's configurations. In 2003 Unit 1 was retrofitted with reburning and OFA systems and in April 2004 underwent reburn optimization testing. Goal of Hg testing in Unit 1 was to characterize Hg emissions while tuning the reburn/overfire air systems for maximum NO_x control performance while maintaining acceptable boiler thermal performance. Understanding of processes that govern Hg reduction in Unit 1 will be used in optimization of Unit 2 reburn system for Hg control.

2.0 Characterization of Mercury Emissions in Unit 1

Western Kentucky Energy's Green Station Units 1 and 2 are identical opposed-wall-fired steam generators manufactured by Babcock and Wilcox, each with a peak generating capacity of 255 MWe (gross). At its maximum continuous rating (MCR), each unit was originally designed to produce 1,840,000 lb/hr of main steam with superheater outlet conditions of 1,005°F at 1,975 psig. Each unit also has a reheat steam capacity of 1,650,000 lb/hr at 1,005°F and 530 psig. The units fire a mix of bituminous coals based on availability.

2.1 Description of the Test Program

Mercury testing in Unit 1 was done at the same time reburn system underwent NO_x compliance testing. Overall activities during the testing period included the following tasks:

1. 0 Firing System Preparation

The initial step in this task was to balance the coal lines and to check the coal fineness coming out of each mill. This task was a crucial step to obtaining the maximum level of NO_x control from the coal reburn system.

2.0 OFA Confirmation Tests

A single set of overfire tests was conducted to verify the NO_x control performance that can be achieved during stand-alone OFA operation. This series of tests measured the NO_x control and thermal performance with 15, 20 and 25 percent OFA.

3.0 Reburn Optimization Tests

The objective of the reburn test series was to maximize the NO_x reduction performance of the coal reburn system while maintaining boiler thermal performance. Simultaneously with NO_x measurements, Hg emissions were also characterized in Task 3.

The test program consisted of 15 tests (Table 1) with the boiler operating under nominal full load conditions at different reburn conditions. Samples 13 a,b,c were collected while Unit 1 underwent 24 hour compliance test at constant operating conditions. Manual Hg sampling using the Fluegas Adsorbent Mercury Speciation (FAMS) and Frontier Total Mercury (FSTM) methods was performed at the ESP outlet. FAMS method is an alternative to the expensive and labor-intensive Ontario Hydro method. Extensive studies[1,2,3] conducted to compare FAMS method with the ASTM promulgated Ontario Hydro Method demonstrated reasonably good agreement between these methods. FSTM is a simplified version of FAMS method that measures total Hg.

During testing fuel samples were collected from each mill and fly ash was collected from the economizer exit duct. Fly ash samples were analyzed to determine loss on ignition (LOI),

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1. Bloom, N.S. (1993) "Mercury Speciation in Flue Gases: Overcoming the Analytical Difficulties." *Managing Hazardous Air Pollutants: State of the Art.* (W. Chow and K. Connor, Eds.), EPRI TR-10189, Lewis Publishers, Boca Raton, USA p. 148.
2. Bloom, N.S., Prestbo E.M., Hall B. and von der Geest E.J. (1995) "Determination of Atmospheric Hg by Collection on Iodated Carbon, Acid Digestion and CVAFS Detection," *Water, Air, and Soil Pollution*. **80**: 1315-1318.
3. DOE, National Energy Technology Laboratory (2001) "Comparison of Sampling Methods to Determine Total and Speciated Mercury in Flue Gas," CRADA 00-F038 Final Report DOE/NETL-2001/1147, Pittsburgh, USA.

results of LOI measurements as well as summary of boiler operating conditions at each test are presented in Table I-1 *Attachment I*. To closely monitor boiler operations, EER also measured CO and O_2 on a dry basis continuously during each test at the economizer exit duct. All measurements were made on the boiler's East side duct. Boiler efficiency was calculated using the ASME PTC 4.1 Heat Loss Efficiency Method. For these calculations, fuel analysis was provided from the actual samples taken during the tests, and the carbon loss was measured from the actual fly ash samples collected during the tests. A heat balance was then used to calculate the actual fuel flow and the plant O_2 measurements were used to calculate the actual airflow.

Coal samples were taken from each mill during the second half of each test period. A composite sample was then assembled by combining coal from the individual samples using relative coal feed rates from the individual mills provided by the plant. The samples were labeled to include the test number, sampling time, and sampling location and sent to an independent laboratory for determinations of ultimate, proximate, and heating value as well as Hg concentration. Table I-2 in *Attachment I* shows composition of tested fuels.

2.2 Mercury Emissions

Tables 1 shows results of FAMS and FSTM measurements. Figures 1 and 2 show results of Hg measurements in a graphic form. FAMS results in Figure 1 for the total mercury are shown in black. Figure 1 demonstrates that Hg emissions at ESP outlet vary from 6 to 10 $\mu g/m^3$. FSTM and FAMS results for total Hg agree reasonably well. Except for Test 2 (Figure 2), FAMS measurements demonstrate that most Hg in flue gas is present in the oxidized form. Surprisingly, very little particulate bound Hg was measured at ESP inlet.

Table 1. Results of mercury measurements.

Test No		FAMS Speciation Results			FSTM Total Hg Results		
		Hg^p	Hg^{+2}	Hg^0	Hg^p	Hg^{+2}	Hg^0
		($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)
1		NA	NA	NA	0.00	5.79	5.79
2		0.01	2.23	7.41	NA	NA	9.64
3		NA	NA	NA	0.00	9.81	9.81
4		NA	NA	NA	0.00	8.38	8.38
5		NA	NA	NA	0.00	6.97	6.97
6		NA	NA	NA	0.01	6.79	6.80
7		NA	NA	NA	0.01	7.49	7.50
8		0.01	5.13	1.88	NA	NA	7.02
9		NA	NA	NA	0.00	6.66	6.66
10		NA	NA	NA	0.00	6.62	6.62
11		0.00	5.97	2.02	NA	NA	7.99
12		NA	NA	NA	0.01	7.30	7.31
13a		NA	NA	NA	0.00	7.57	7.57
13b		NA	NA	NA	0.01	7.26	7.28
13c		0.00	6.00	1.42	NA	NA	7.42

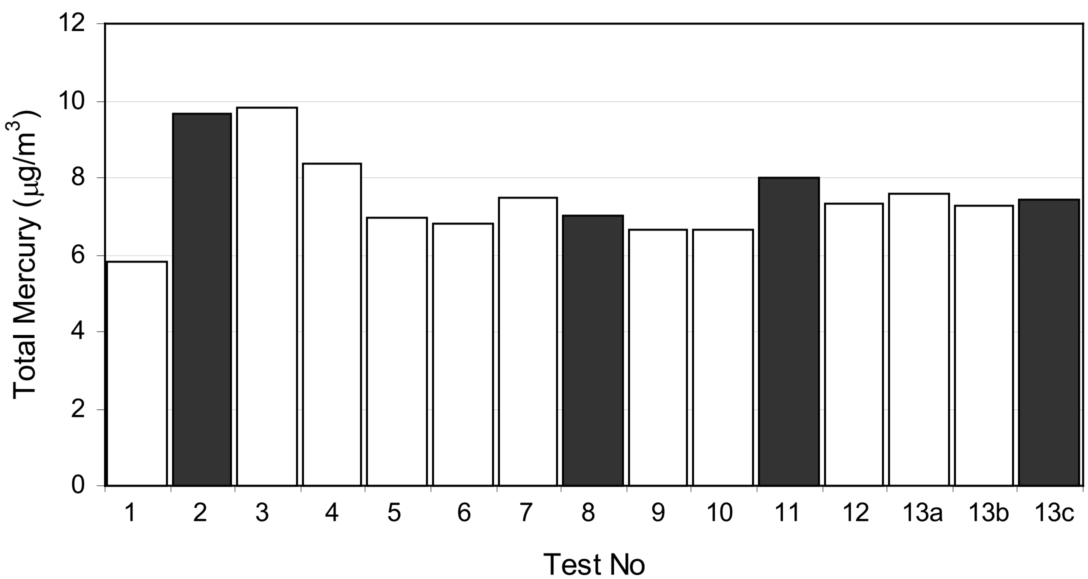

Figure 1. FAMS and FSTM results for total mercury.

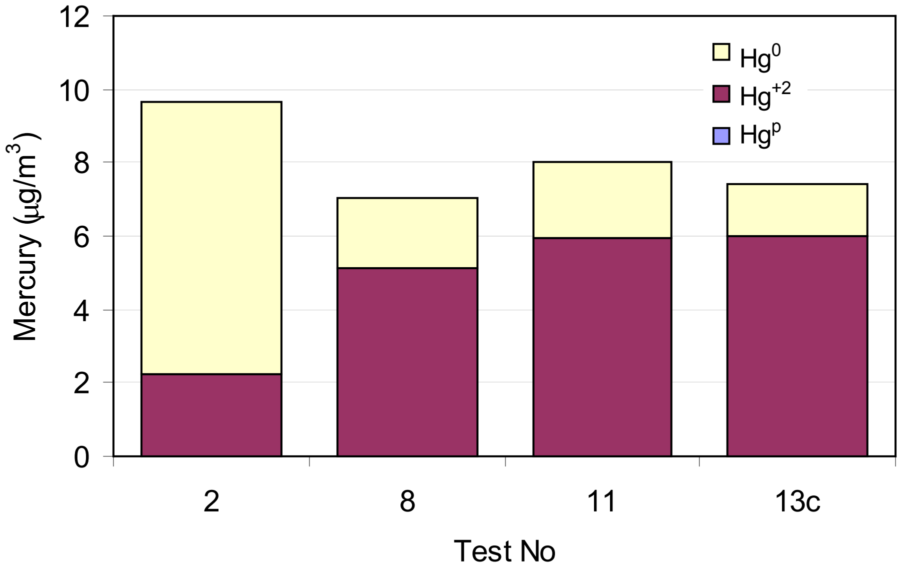

Figure 2. FAMS results.

Figure 3 shows efficiencies (defined as a difference between theoretical Hg concentration in the gas phase calculated using coal feed rate and coal Hg content and that measured) of Hg removal at ESP outlet. Testing showed that efficiency of Hg removal varied from 6% to 36%. Efficiencies of Hg removal less than 10% were measured in tests 2 and 3, all other tests showed efficiency of Hg removal 20% or greater. Table I-2 shows that Hg content in coal varies from 63 ppb to 81 ppb, about 30% variation. Coal sample were taken from mills during each test. Because of the time difference between coal sampling and actual delivery of the same coal batch to the furnace, and because duration of each Hg test was only about 20 minutes, this high variability in coal Hg content may have resulted in relatively high uncertainty in Hg removal efficiencies.

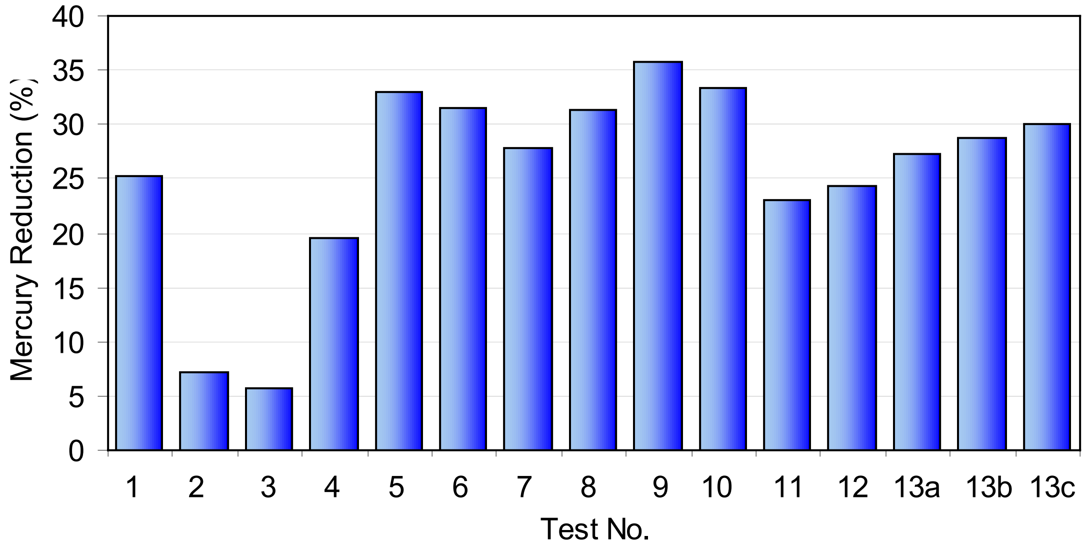

Figure 3. Mercury reduction at ESP outlet.

Figures 4 shows comparison of Hg removal efficiencies measured at ESP outlet in Unit 1, Unit 2 and pilot-scale measured previously[4]. Figure 4 shows that Unit 1 data are in general agreement with pilot-scale and Unit 2 measurements.

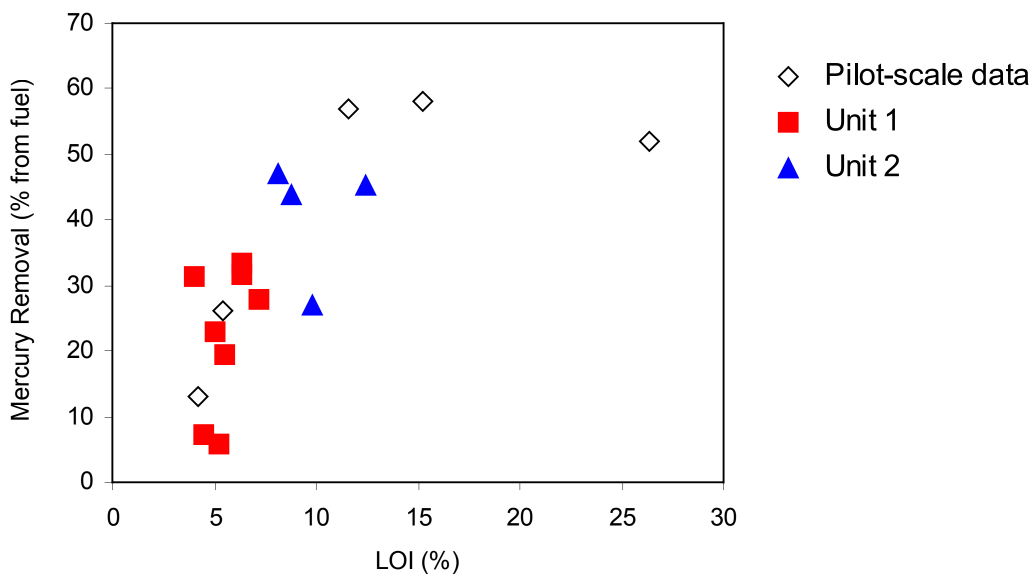

Figure 4. Comparison of pilot-scale and data on Hg removal in Units 1 and 2.

4. Lissianski, V. and Marquez, A. “Preliminary Field Evaluation of Mercury Control Using Combustion Modification”, Annual Report, DOE Contract No. DE-FC26-03NT41725, February 2004.

3.0 Future Work

Additional round of Hg testing at Unit 2 is planned in September 2004. During these tests reburning system will be operated at deeper staging conditions to provide deeper Hg control. Analysis suggests that at optimized conditions, mercury removal at ESP outlet is expected to be in the range of 70-80%. Even deeper NO_x control than that previously achieved can also be expected.